HXMA BL Operation Notes: Off-Tuning Effect at HXMA Monochromator

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1. Introduction

The performance testing carried out recently at HXMA has indicated that the detuning at monochromator 2nd crystal has apparent impact to the X-ray vertical beam positioning at HXMA sOE. Proper tuning the mono crystal can stabilize the X-ray beam at a constant vertical height within the error bar of the currently adopted investigation scheme (detail in *HXMA operation notes: 01-09-2010 and 01-10-2010*). A following-up experiment was performed to investigate a "natural" off-tuning process, which is beyond the interference, e.g., motor motion, and solely controlled by the power lading at the optics, and the thermal response from the optics to their loaded power.

2. Experimental

The experiment was started right after the storage ring injection at 23:01 Jan 16, 2010, thus highest power from HXMA wiggler source was loaded at optics in HXMA pOE. A fully tuning was performed at $\theta 2$ mechanism of the mono 2nd crystal to adjust the two mono crystals parallel to each other as a initial condition of the experiment. No further tuning or detuning was performed afterwards, and the mono crystals experienced its off-tune process without interference. The experiment spanned an I_{ring} current range from 245.3 to 210.3 mA, and was terminated because of a storage ring trip. The total experiment time is 147 minutes, and the experimental detail was summarized in Table 1.

During the experiment, the JJ X-ray slits vertical center was scanned repeatedly to obtain the vertical cross section of the X-ray beam profile in step with the I_{ring} decay. The total motor scan range is -200 to 200 μm relative to the nominal beam vertical center of the time with a spatial resolution of 5 μm. No motor was moved at any optics within the HXMA pOE to eliminate any unwanted effect to the crystal off-tuning and the beam vertical positioning. Thus the thermal effect from the I_{ring} was the only be considered contributory variable to the off-tuning effect.

The maximum flux point on the curve of the vertical cross section was obtained, and referred as vertical beam center. It is realized that the scheme to determine the beam center might be not exactly the hot spot vertically, but since the same scheme has been used consistently throughout the experiment, therefore the error in the positioning is believed to be a systematic type. Furthermore the focus of the this experiment is to explore the trend in beam vertical repositioning controlled by the effect of the off-tuning from the mono 2nd crystal, rather than the beam actual position, the possible error mentioned above form the experiment scheme is ignored.

Figure 1 shows the trend of the liner decay in the storage ring current I_{ring} versus the time. Here the time is relative to the moment when the beamline frontend photon shutter was opened, which is recorded as 0 in time. During the time scope of the experiment (2.45 hrs), the ring current decayed by 35 mA with a decay rate of 0.25 mA/min. Figure 2 displays the response trend of the I0 output versus the time (solid circle) and I0 versus I_{ring} (crossed open circle). Not surprisingly, the linear correlation (Figure 1) is lost in

Figure 2 because of the off-tuning of the mono 2nd crystal. Since the off-tuning was progressively affected by the combining effects from the power loading and the cooling contribution from the LN2, and the balancing between the two, the two trend curves shown in Figure 2 are generally smooth and continued, but both strongly curved. This observation is in consistent with the results reported previously in the Beamline operation Notes (01-10-2010) regarding detuning effect.

Table 1. Summary of experimental detail

BL components	Operation status	
Experiment date	Jan 16, 2010	
Operator	Weifeng Chen, Ning Chen	
HXMA Wiggler	1.9 T	
Storage operation mode	250 mA	
Graphite filter(s)	Out of beam path	
Primary slits	$1^{(v)} \times 8^{(H)}$ mm^2	
Mirror	Collimating	Pt stripe (pre-mono)
	Toroidal	Pt stripe (post-mono)
Mono	Crystal	Si(111)
	Energy	10 KeV
Detector	I0	Straight ion chamber filled with 100% N_2
	Detune	Photo diode at WB pipeend
Beam pipe setup	Between WB pipe end and JJ slits, He filled	
JJ slits	Opening	$10^{(v)} \times 10^{(H)}$ mm^2 when recording I0
		$0.5^{(v)} \times 10^{(H)}$ mm^2 when scanning JJ slits vertically
	Scan mode	Single scan(backlash calibrated)
Experiment scope	I_{ring} from 245.3 to 210.3 mA, Δ=35 mA Time: 147 minutes in total	
Detune	Rate	Fully tune at beginning of experiment, No further detune followed
	Energy	10 K eV

In Figure 3, the 1st derivative of the I0-Time trend is overlaid to the trend it selves. It clearly reveals that the 1st derivative curve, which represents I0-Time decay rate, can be divided into three sections. The 1st section starts from the time to open the shutter, and extends to ~ 20 minutes, characterized by a very rapid decay in I0, thus strong off-tuning effect is obviously observed. For example, after shutter opened by 7 minutes, the decay rate is more than 90 (mV/min). The 1st section is then followed by the 2nd one, featured by a much shallower decay rate ranged roughly between 28 - 15 (mV/min). In 3rd section, which starts at ~30 minutes, the decay rate is less than 13 (mV/min). This decay rate is acceptable for XAFS. After 2 hours the rate further decreases to a level less than 2 (mV/min). The beam is stabilized.

Similarly to what presented in Figure 3, the 1st derivative of the I0-Iring trend is overlaid to the I0-Iring trend in Figure 4. Again three sections are revealed along the decay curve. At beginning of the experiment when shutter was just opened, the off-tuning is extremely strong, resulting in a decay rate of 387.5 (mV/mA). The 2nd section is for I_{ring} range between 243 – 237 mA with an average decay rate of ~40 (mV/mA). Then followed is the 3rd section, where I0 is stabilized with a decay rate of ~10 (mV/mA).

In general the data shown in both Figures 3 and 4 are supporting each other, and consistent with data presented in Figure 2.

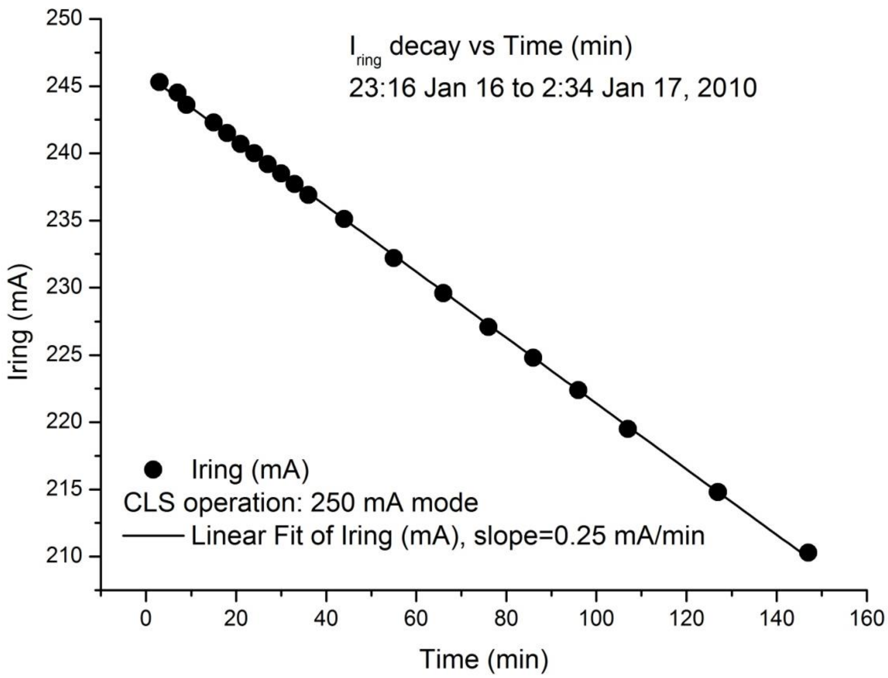

Figure 1. The liner trend of the storage ring current versus the time. Notice that the decay rate is 0.25 mA/min on during the time when the experiment was performed.

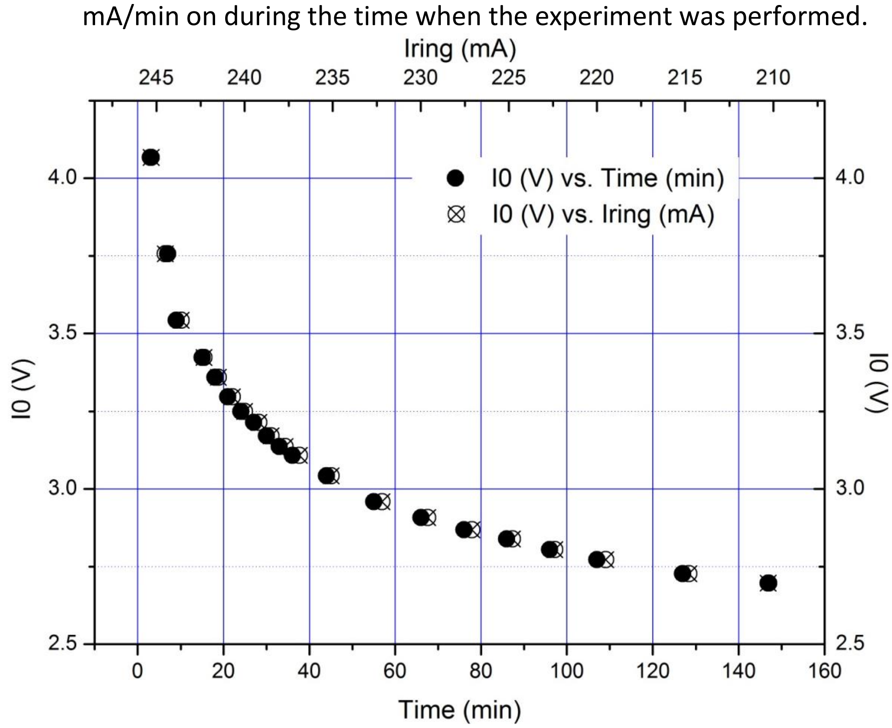

Figure 2. The response of I0 to time (solid circle) and to the I_{ring} (crossed open circle). Here the left and right vertical axes are identical. The bottom and top X axes are for time and I_{ring}, respectively.

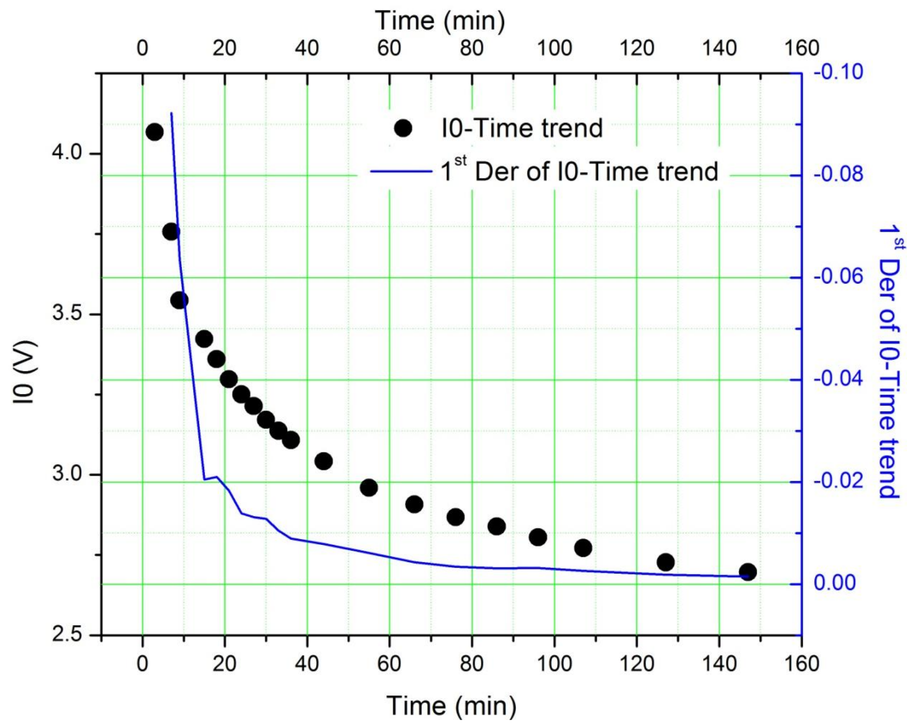

Figure 3. Comparison between I0-Time trend and the 1st derivation of the I0-Time trend. The later is blue in color for both of the trend curve and its Y axis (right Y axis).

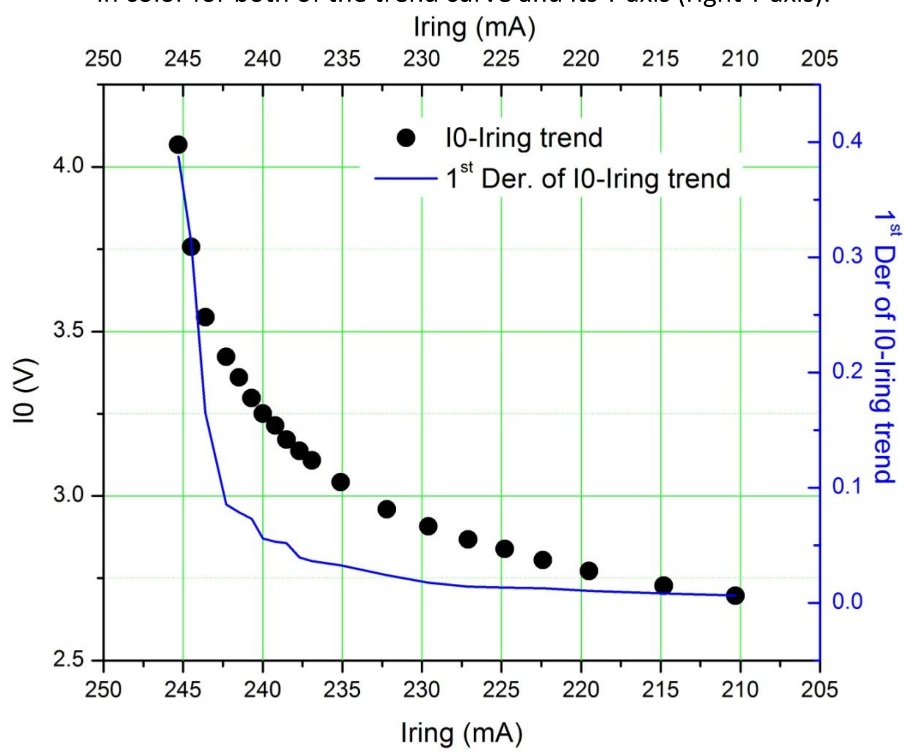

Figure 4. Comparison between I0-Iring trend and the 1st derivation of the I0-Iring trend. The later is blue in color for both of the trend curve and its Y axis (right Y axis).

3. Results and discussion

The vertical cross section data for the X-ray beam profile collected under different off-tuning condition was shown in Figure 5. The data was vertically stacked with a constant offset. Two phenomena are observable herein. At first there is noticeable difference in the amplitude of beam cross section within the identical JJ X-ray slits scanning range (400 μm in total), indicating that I0 sensed flux was changed in accordance with the off-tuning process, and is consistent with the flux data shown in Figures 2-4.

Secondly, the total off-tuning process divides into two phases, namely positively tuning at first and followed by a negative tuning. Right after the mono saw the beam, the two mono crystals lost their fully tune status (parallel to each other), and the 2^{nd} crystal began to off-tuning to the cw direction (seen form inboard). This process finished at ~20 minutes when a certain “critical” θ2 angle position (relative between the two mono crystals) was reached, and then off-tuning process was reversed. It is expected that this critical point is mono crystal temperature dependent, therefore related to how long the mono has been cooled down (because of injection, or ring trip), I_{ring} (total power loading), the mono operation energy (i.e., Bragg angle θ, which determines the X-ray beam footprint on mono crystal), and which crystal is in the beam path. Therefore the point might have a distribution range, rather than a single point. For the convenience of study, the vertical cross sections (Figure 5) were normalized, and represented in Figure 6. In this way the inverse in off-tuning direction is more clearly displayed.

Figure 7 shows the two phase of off-tune process versus the time. The “critical” point is at ~20 minutes after the optics began to expose to the X-ray. In the phase one under positive off-tuning, the beam position vertically changed rapidly, while in the phase two after switching to the negative off-tuning, the position changing rate is progressively decreased till the end of the experiment. Figure 8 shows the two phase off-tune process versus I_{ring}. Similar discussion can be made as those for the off-tune process versus the time. But here the “critical” point of I_{ring} is 241 mA.

Figure 9 shows the correlation between off-tune processes for I0 and for the beam vertical position. Here the critical points are 3.24 V for I0 and 422 μm for beam vertical position, respectively. More interesting is that although I0 is in general decreased during the off-tuning process for both positive and negative scenarios, there is a tendency to recover both I0 and beam vertical position, which occurred close to the end of experiment (very last three data points in the graph, Figure 9), which correspond to the time of 100 minutes after the shutter opened (Figure 7) under a storage ring current of 220 mA and lower (Figure 8).

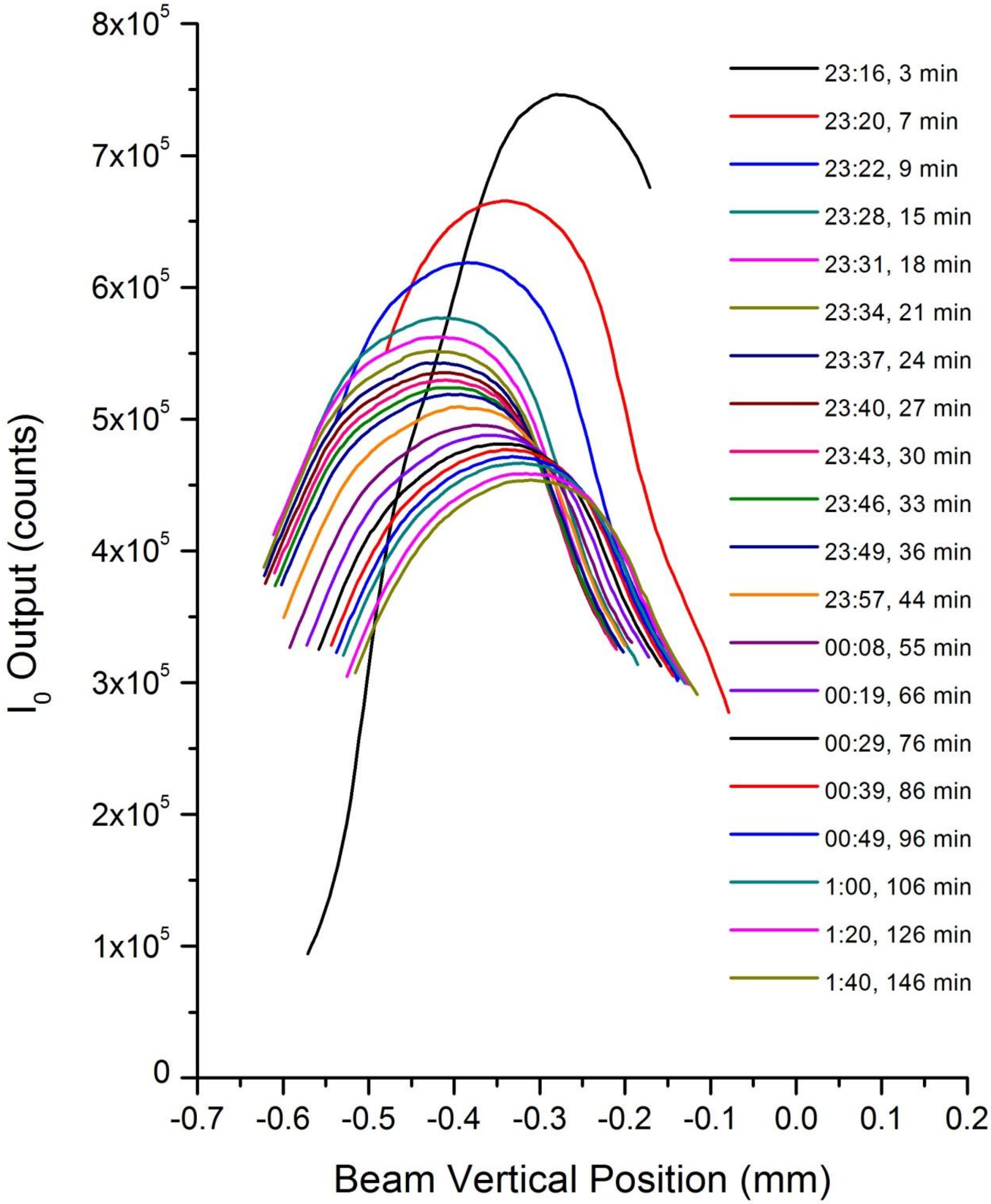

Figure 5. The vertical cross section of the X-ray beam profile obtained at different time after the frontend photon shutter was opened. The time when each data set was collected is listed as the column on the left, absolute time followed by the relative time (versus the time when the frontend shutter was opened).

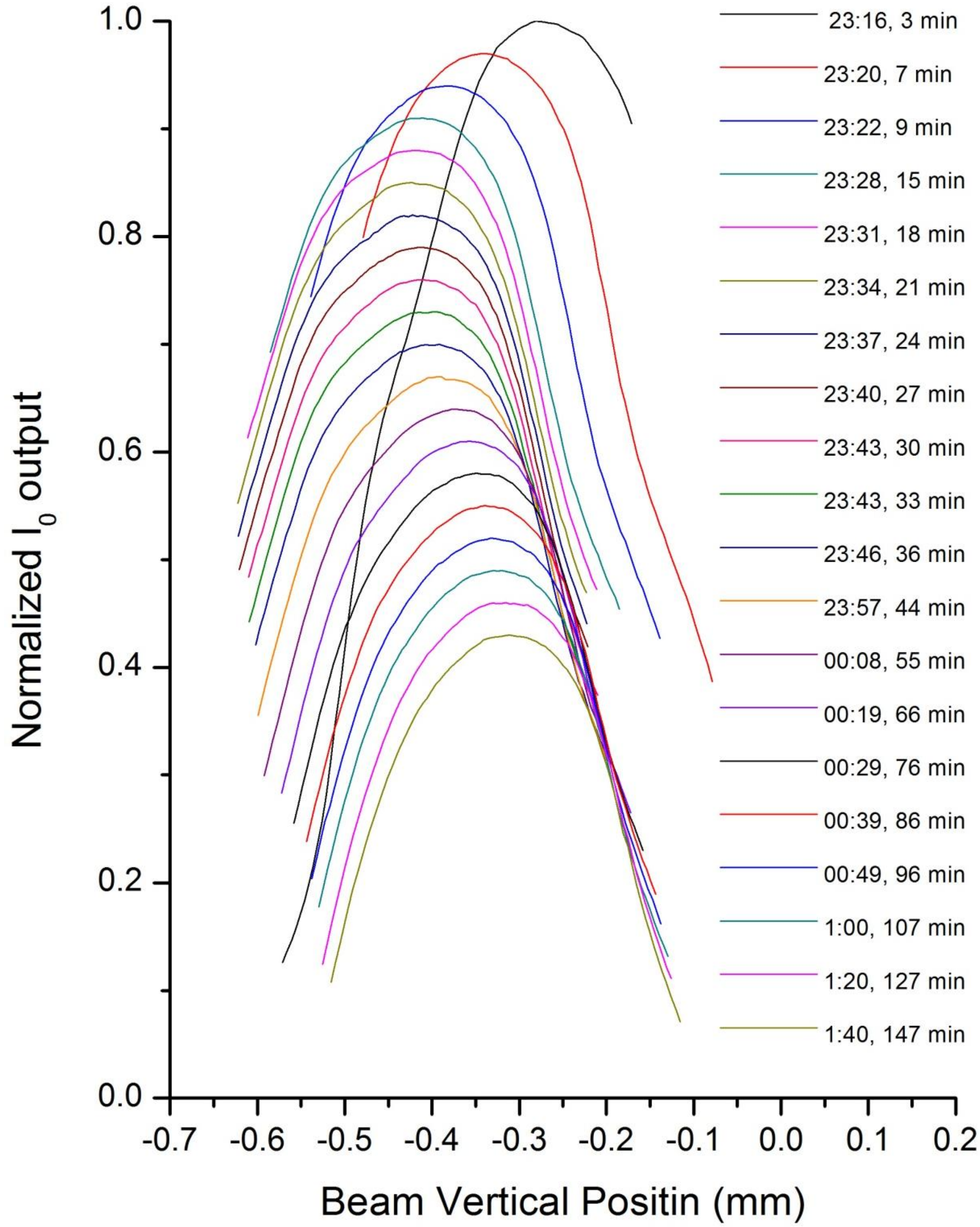

Figure 6. The normalized vertical cross section of the X-ray beam profile obtained at different time after the frontend photon shutter was opened. The time when each data set was collected also is listed as absolute time, followed by the relative time.

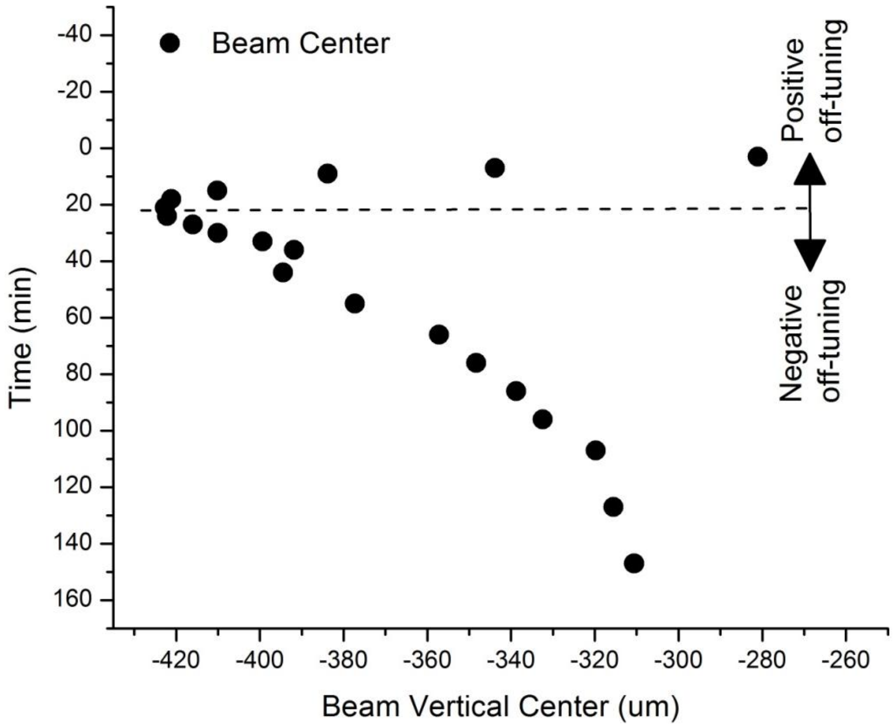

Figure 7. The positive off-tune process observed at the early stage of the off-tune process, and the negative off-tune process proceeded after the “critical” point.

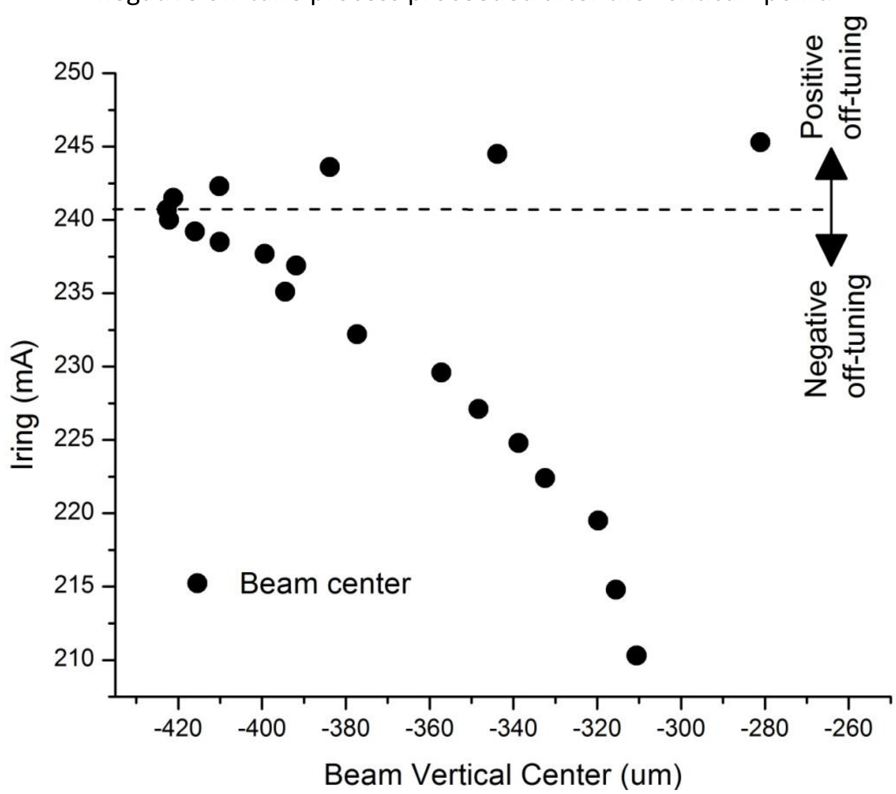

Figure 8. The positive off-tune process turns into a negative off-tune process with a “critical” point at I_{ring} of 241 mA.

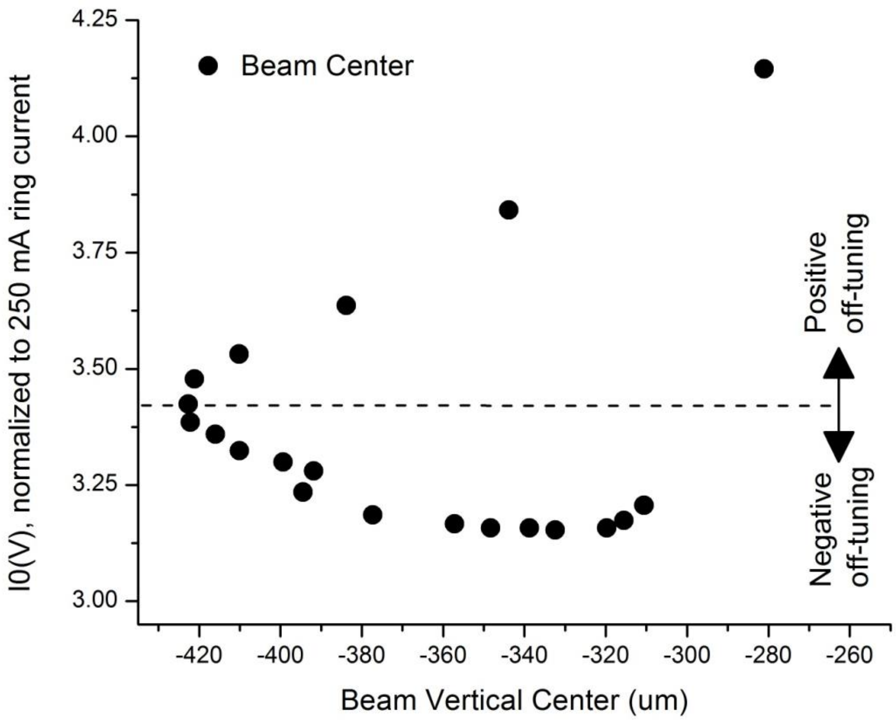

Figure 9. The correlation between off-tune processes. Here the I0 voltage readout has been normalized to 250 mA storage ring full current.

4. Conclusion

Based on the data collected through this experiment, following tentative conclusions can be made:

1. Beam lost at BL optics, especially mono crystals, will cause mono crystal off-tune from their original setup. After the beam is restored, the mono crystals will undergo an off-tuning process, which drives the mono θ2 mechanism away from its original tuning status, and moves the X-ray beam vertically;
2. The off-tuning process starts with a positive off-tuning first, and then transfers to a negative off-tuning. There is a critical point between the two phases in terms of time (Figure 7), I_{ring} (Figure 8), I0 and beam vertical position (Figure 9);
3. It is expected that the critical point will be affected by multiple operation related factors, including storage ring current, mono temperature, mono operation energy, tuning or detuning status before the beam lost, how long the beam being lost, and which crystal is in the beam path; and the critical point might have a range, rather than single points;
4. The off-tuning process might be able to turn into a turning recovery process in terms of both beam position and I0 as the tendency shown in Figure 9. But since it is not observable till ~100 minutes after beam is restored, and scope of the recovery is yet unknown, this effect practically cannot be relied on in operation.
5. Proper retuning after beam restored is absolutely necessary, but it is expected that the retuning will not work effectively within the first 20-30 minutes after the beam is back because of the strong off-tuning effect.